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## Research into the Impact of Western Budworm on Forest Planning

Measuring economic impacts of forest insects, such as the spruce budworm, is an indirect process concerned primarily with how the insect's outbreak activity affects the sustained flow of timber and other services from public and private forest lands. Research is being conducted at Oregon State University (OSU) to determine the economic impacts of this pest.

Under the Resources Planning Act (RPA) and the National Forest Management Act (NFMA) in the United States and policy measures derived from the Sloan Commission study completed in 1945 and the more recent Pearce Commission Study in British Columbia, the area of forest lands managed for sustained yield under long-term planning objectives has been increasing in the Western United States and British Columbia. Eventually the majority of forested land will be subject to long-term planning objectives. Forest yield projections are an important input to the forest planning process as it has evolved in both the United States and British Columbia. These projections are usually expressed as a volume table, yield table, or timber production table. The budworm can have an impact on forest plans by affecting timber yields through growth loss, top kill, or mortality.

As suggested above, forest planning in the Western United States and British Columbia is developing along somewhat different lines, although timber yield assumptions are important in both places. In the United States, forest planning developed under the mandates of RPA and NFMA is being accomplished by implementing the FORPLAN algorithm. Harvest scheduling in that algorithm uses the MUYSIC algorithm. The objective throughout the RPA/NFMA planning process, the FORPLAN algorithm, and MUYSIC as well, is to maximize the present net worth of the flow of forest services over time. That objective is subject to a set of operational and administrative constraints that include even flow objectives and potential forest yields.

In British Columbia, forest planning currently defines levels of annual allowable cut and is directed at maximizing the volume of timber production subject to multiple use, even flow, and potential yield constraints. An algorithm like FORPLAN that explicitly addresses multiple land-use decisions has not been adopted by the British Columbia Ministry of Forests (BCMF) at present. Some of BCMF's harvest schedule planning for Timber Supply Areas is aided by MUYSIC or Timber RAM algorithms. On the other hand, some Tree Farm license planning done by the private sector and subject to BCMF approval is done on an area volume allotment check procedure that ensures sufficient timber volume can be obtained to meet existing or anticipated forest product production capacity over time. In the future,

maximizing present net worth of forest services provided over time may become a planning objective in British Columbia as well.

Budworm-induced yield impacts can affect forest plans in either country in several ways—making planned harvest schedules or other objectives subject to flow constraints over time impossible to achieve, reducing maximum volumes expected to be available for harvesting under a plan, and reducing a plan's present net worth. In addition, budworm-altered yield impacts can lead to reclassification of marginally productive timber land to other uses, thereby reducing a plan's acreage base for timber harvest.

OSU research has been investigating economic costs of budworm activity according to the potential the insect's forest yield impacts have to affect plan objectives. Those costs have been included in an investigation of the direct dollar impacts associated with budworm outbreaks. The research has been concerned with the fact that yield reductions in a forest managed for even flow can lead to economic losses greater than the losses that would be incurred when damage occurs or when damaged trees are harvested. That is, in forests managed for even flow objectives, individual yield impacts would be distributed throughout the time period covered by the management plan as harvest levels throughout the plan are adjusted to compensate for what would be, in effect, new yield tables.

This effect is well recognized in the context of intensive forest management and creates an impact upon a long-term plan through the so-called allowable cut effect. What has not been generally recognized is that outbreaks of western spruce budworm during a plan can lead to the reverse allowable cut effect for harvest volumes within a plan. In terms of the pest's economic impacts, this implies that anticipated yield losses (or those projected by CANUSA research) in a forest should be evaluated for the values associated with harvest volume reductions, or losses whenever they occur in the planned harvest schedule. Total budworm economic impacts then have the potential to be larger than the amounts currently estimated for some budworm-caused damage in the typical environmental impact statements prepared for budworm outbreaks.

Evaluating budworm impacts in terms of forest planning objectives and requirements can help forest managers decide how to effectively implement CANUSA-developed monitoring and control strategy programs by assessing their value in the context of a particular forest plan. For example, in the United States, forest managers will have a basis for evaluating the worth of silvicultural methods that would reduce the budworm's impacts on yields by calculating the difference between the present net worth of plans developed alternatively

with, and without, budworm yield impacts that silvicultural methods would avoid. Managers will then be able to compare the costs of treatment to that difference. The gain in a plan's value through the use of viable silvicultural alternatives would be greater than the cost of implementing those alternatives.

In British Columbia, where volume maximization is the forest planning criterion at present, budworm control and noncontrol plans can be compared to assess the impact of the insect upon total planned yield over time. Decisions can then be made whether or not silvicultural treatment is justified in terms of total harvest volume differences over time between the two plans.

Researchers at OSU have consulted forest planners, private landowners and producers, and forest managers to determine the type and form of budworm-impacted yield information that facilitate forest operations and planning. In each instance, the importance of expressing budworm yield impacts in terms of the timing of merchantable volume losses was underlined. The impact of budworm yield impacts upon harvested volume throughout the planning horizon—whether expressed as volume changes or changes in present net worth—was also included as an important consideration for forest management.

To date, the OSU research has introduced yield changes based upon hypothetical budworm scenarios by constructing yield tables for harvest schedules generated by MUYSIC and Timber RAM. Those algorithms have been run for typical forest types on the east side of the Rocky Mountains to determine whether budworm yield impacts would appear to forest planners and managers as harvest volume changes or plan infeasibilities. The costs or losses that would have been associated with each budworm scenario were then calculated as differences in total present net worth between plans impacted by budworm and plans not impacted.

At the present time, however, precise and reliable data on budworm-affected yield impacts on merchantable volume are not available. Research begun by Alan Van Sickle and currently being conducted at the Pacific Forest Research Centre by René Alfaro, investigating variation in tree form recovery after a budworm outbreak, is an important input to the research being done at OSU as we explore ways to assess budworm-induced changes in merchantable volume rather than changes in total yield table volumes.

At present, results are hypothetical, although the structure of the analysis may provide important data for forest planners and managers. As more accurate estimates of the insect's effect on yield or volume become available, we will be able to assess more accurately the overall impact of western spruce budworm in terms of dollar or timber production volume losses throughout a forest planning horizon.

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## **Budworm Genetics**

Blue eyes or brown eyes? Tall or short? Blonde or brunette? These are burning questions for new parents as they peer at their offspring and try to decide which features came from whose side of the family. Although this may be the closest that some of us get to genetics, in biology today genetics is a vital science, growing at a rapid rate. Almost daily we read reports in our local newspapers of progress in genetic engineering for curing human disease, or we are reminded of the marvelous successes of plant breeding that marked the Green Revolution. These are sterling examples of the application of genetics for human welfare, and pest management provides another arena for its benefits. The entry of genetics into forest insect management is relatively new, but the payoffs promise to be big, and spruce budworm is no exception.

What does genetics have to do with the spruce budworm? Consider three situations where CANUSA-funded investigators are working to find out. The first one takes us to a population of western spruce budworm in about the third year of outbreak on Douglas-fir in Idaho. Tradition holds that the insects are a fairly homogeneous lot and not much different from those in neighboring populations across the border in Montana. But the facts show that this is far from the true picture. Molly Stock at the University of Idaho in Moscow measured the genetic variability in these populations by a technique called electrophoresis. Suspensions of ground-up larvae or moths are subjected to an electric field on a gel. Isozymes, chemically different enzymes coded for by different genes, migrate at different rates on the gel. The Montana and Idaho populations of western spruce budworm differ a great deal in isozyme

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<sup>1</sup>Bibliography for this article:

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content (i.e., genetic makeup). Stock is currently examining the relationship between outbreak patterns in these areas and patterns of genetic similarity.

This is not the only way that Stock has studied the implications of genetic variability in western spruce budworm. In collaboration with Jacqueline Robertson, at the Pacific Southwest Forest and Range Experiment Station in Berkeley, she tested western spruce budworm from different locations for susceptibility to insecticides. This experiment yielded two important results. First, not only populations, but sibling groups (families) were quite different in their response to the chemicals. This fact demonstrates that insecticide response levels are genetically based. Second, genotypes of insects that survived chemical treatment were different from the genotypes of insects that were not treated. This last result means that treatment itself selectively removes genotypes from the population, genetically "rearranging" them, and potentially decreasing their susceptibility to chemicals.

Electrophoresis is a very popular technique for measuring genetic variability in all sorts of living things, and George Harvey at the Great Lakes Forest Research Centre in Sault Ste. Marie has adapted it for use for *C. fumiferana*. He is surveying populations from Newfoundland to Alberta, analyzing larvae or moths attracted to pheromone traps. Harvey is looking for any genetic indicators of outbreak age, density, or location. Developing a genetic "early warning system" is an exciting possibility for the future.

The third example of CANUSA research on the genetics of budworm comes from my own work at the North Central Forest Experiment Station in St. Paul, where I also measure genetic variability, not only from population to population, but from tree to tree within populations. I wanted to see if host tree species could influence the survival of particular insect phenotypes, and they do. In some populations caterpillars from white spruce have significantly different numbers of heavily melanized individuals than caterpillars from balsam fir. The latter are generally darker. Insects collected from Maine and New Hampshire also have different color frequencies than insects collected from Minnesota and Wisconsin. Other data being analyzed include measurements of traits that are completely genetically determined, like pupal color and moth wing color, and traits that also have an environmental component, like pupal weight and female fecundity.

The current CANUSA effort is not the first interest in the genetics of *Choristoneura*. Canadian researchers utilized a genetic approach when working out the taxonomy of the genus in the 1950's and 1960's. Stock and her research associate, Paul Castrovillo, are extending these taxonomic studies.

All studies have documented genetic variability: individual budworms differ from one another in their inherited traits. Now researchers are interested in the source of the variability. For example, populations may be

genetically different because they are in different geographical locations, because they are different ages in terms of outbreak, or because of different treatment histories. Differences among insects within populations could be due to recent migration or different species of hosts. Although we are only in the early stages of realizing the benefits of genetics in forest insect management, CANUSA is in the forefront of this venture. CANUSA's support is significantly stimulating creative application of this new approach.

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### Modelling Western Spruce Budworm Population Dynamics and Impact

Models ranging from simple mathematical descriptions of specific relationships to complex computer simulation programs, have an increasingly significant role in the development of pest management systems. Three "levels" may be defined on a spectrum of model applications for management:

- (1) "tactical" models for day-to-day decisionmaking;
- (2) "strategic" models for decisionmaking about different types and strategies of pest control or stand treatment, and
- (3) "policy" models for decisionmaking at a national or regional level.

Utility of a particular model must be judged in terms of the level at which management guidance is sought, as each of these levels of management has different temporal and spatial scales and levels of resolution of system biology. A single model should not be expected to meet all management needs effectively.

As an example pertaining to budworm, imagine the following two hypothetical cases. The first concerns timing of the application of a control agent on a stand of budworm habitat. The decision to apply the control agent has already been made, but the best sequence and timing of application to achieve maximum efficacy must still be determined. The second case concerns the effects of budworm on harvest scheduling on a National Forest for a single rotation. Clearly, these are two different management problems that can only be addressed effectively by different models. The first case would likely require a development model, with temperature-related effects on foliage and insect growth rates simulated with a daily time step. The economics of timber supply and demand, although important in the initial decision to use a control agent, would not need to be considered. The second case would likely treat budworm biology simply in the content of frequency and

severity of outbreaks, given prior knowledge of budworm history in the area or in areas with similar characteristics. Instar-to-instar mortality and growth of budworm would be superfluous to this type of analysis. It is difficult to imagine a single model that would serve both purposes.

The CANUSA-West Program has developed a "strategic" model for western spruce budworm, specifically designed to assess different silvicultural and harvesting strategies and control applications on budworm populations, defoliation, and forest yield over a forest rotation. To accomplish this, a budworm submodel was incorporated into a USDA Forest Service stand PROGNOSIS model presently being used by forest managers in the Northwestern United States. Behavior of a modified form of this system is currently being analyzed by a CANUSA-funded economist within the context of the FORPLAN "policy" model. Many of the relationships with the budworm submodel and its linkages with the PROGNOSIS model are, in turn, generated by research-oriented or "tactical" level models developed by CANUSA investigators. These relationships will also be of value to forest managers in areas where the PROGNOSIS model is not currently a management tool, for incorporation in other "strategic" and "policy" models. "Tactical" level, research-oriented models of western spruce budworm population dynamics and impact are being developed at the Pacific Forest Research Centre (PFRC). Studies commenced there in 1976, before the CANUSA program, with development of a population dynamics model used to identify critical gaps in our knowledge of the system, and to guide subsequent research into key relationships, notably larval emergence-bud burst phenology and dispersal patterns in relation to mountainous topography. Numerical wind models for mountainous terrain, being developed by the PFRC meteorologist, will be used to help define dispersal patterns.

Although models of budworm population dynamics are essential for evaluating control strategies, many of the needs of the forest manager may be met by pest impact models, e.g., prediction of losses from the expected duration and severity of defoliation. Such models are being developed at PFRC separately from the population dynamics work as they are based on intensive damage appraisal sampling programs, with a consequent increase in reliability over the population models where there are gaps in our knowledge of some key processes.

As part of the damage appraisal program, stems were sectioned and the annual radial and height growth were measured. The annual growth of the bole, based on such data, can be reconstructed, and an example appears in figure 1a. The tree has been subjected to four budworm outbreaks in its 90-year life. The discontinuities in the bole represent the effects of dieback and the interruption of height growth resulting from budworm attack. These stem deformities are grown over in the tree, but we do not attempt to recreate this in our system.

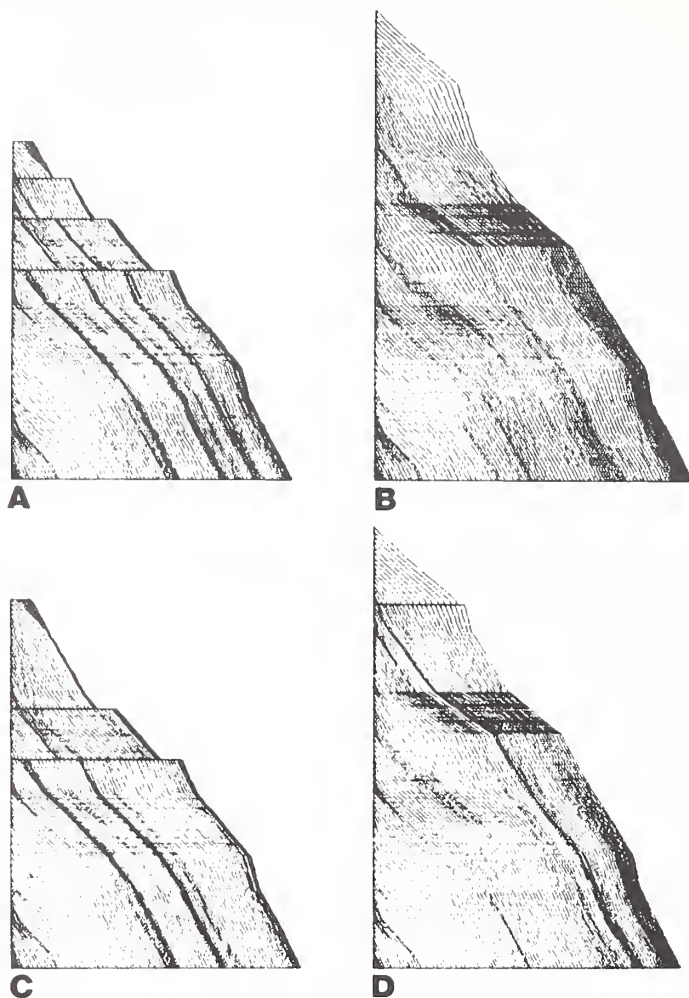


Figure 1: Computer-drawn representation of annual bole outline of: (a) actual tree showing four outbreaks; (b) potential tree; (c) tree with one outbreak controlled, and (d) tree with one outbreak studied in isolation. The radial scale is greatly exaggerated for clarity.

Potential growth was estimated from pre- and post-outbreak growth rates, and the tree was reconstructed as if no outbreaks had occurred (fig. 1b). Alternatively, the effects of controlling one outbreak can be determined (fig. 1c), or one outbreak can be examined in isolation (fig. 1d). In addition, the impact of height growth losses or radial growth losses can be investigated separately. Studies so far suggest that height losses early in the rotation are more important than radial losses, while late in the rotation, radial losses are more significant.

Defoliation intensity during the most recent outbreak was estimated each year for each tree, which was subsequently cut for growth measurement. We have recently quantified the relationship of defoliation to growth loss in a manner that incorporates both current defoliation level and defoliation history.

When budworm effects on tree growth are incorporated in stand models, the results of many simulation runs can be summarized in a form readily useful to forest managers. A stand model with user-specified height/age, diameter/age, and mortality rates was

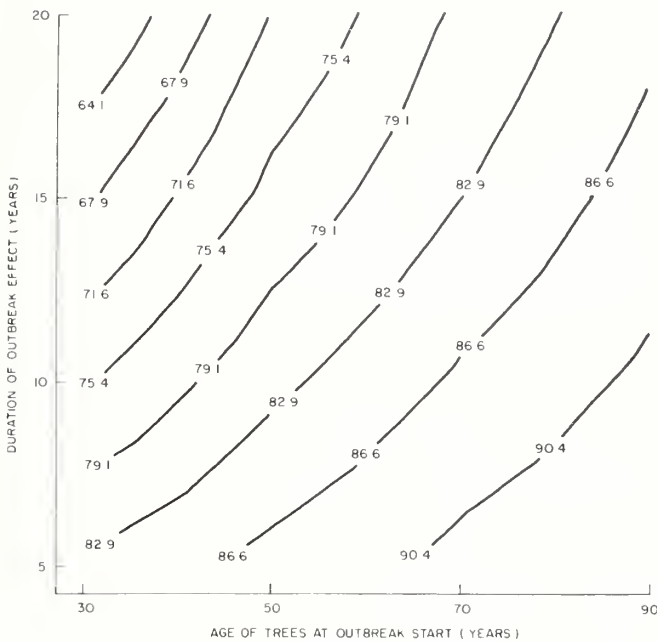


Figure 2: Stand volume at rotation as a percent of potential stand volume, for a hypothetical stand subjected to varying levels and timings of defoliation in a stand model.

developed at PFRC, and budworm impact, including both active defoliation and recovery effects, was specified for different durations at different points in the stand development. The type of output that can be obtained is illustrated in figure 2, which shows stand volume as a percentage of the potential stand volume at rotation in relation to stand age at the start of a single outbreak and the duration of the outbreak effects, including the recovery period, in a hypothetical stand.

A set of such figures might be constructed for merchantable volume and other management-related outputs, as well as percent potential volume, for a wide range of stand-development types. The forest manager can then select the figures appropriate to his particular situation.

In summary, a single model cannot fulfill all management needs. To guide the decisionmaking process effectively, a range of models must be tailored specifically to particular management objectives or missions. This may be accomplished by incorporating pest sub-models or pest impact relationships in existing management systems, as with the CANUSA-West model. Research-oriented models, such as those developed at PFRC, are used to generate readily incorporated relationships for inclusion by forest managers in whichever system best meets their requirements.

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### Spruce Budworms Situation in 1981

The spruce budworms continued to have a significant impact on large areas of forest in Canada and the United States in 1981. In the East, visible defoliation of balsam fir and spruce by the spruce budworm, *Choristoneura fumiferana* (Clem.), occurred over 38.8 million ha (96.0 million acres). Tree mortality continued and was recorded within an area totalling 25.8 million ha (63.7 million acres). Operational spray programs, covering a total of 3.4 million ha (8.5 million acres), were carried out in Newfoundland, Nova Scotia, New Brunswick, Quebec, Ontario, and Maine. Forecasts for 1982 indicate that the area of defoliation will increase to 49.5 million ha (122.3 million acres). The following table summarizes data on the outbreaks of the spruce budworm by province and state.

| Province<br>or<br>State | Area of<br>Visible<br>Defoliation |                  | Area with<br>Dead and<br>Dying Trees |                  | Area<br>Sprayed |                  | Area of<br>Defoliation<br>Forecast for<br>1982 |                  |
|-------------------------|-----------------------------------|------------------|--------------------------------------|------------------|-----------------|------------------|--|------------------|
|                         | (X1000<br>ha)                     | (X1000<br>acres) | (X1000<br>ha)                        | (X1000<br>acres) | (X1000<br>ha)   | (X1000<br>acres) | (X1000<br>ha)                                  | (X1000<br>acres) |
| Newfoundland            | 380                               | 939              | 427                                  | 1 055            | 240             | 593              | 154  | 381              |
| Nova Scotia             | 567                               | 1 401            | 1 200                                | 2 966            | 31              | 76               | 200  | 494              |
| Prince Edward<br>Island | 133                               | 329              | 25                                   | 62               | —               | —                | 100  | 247              |
| New Brunswick           | 1 221                             | 3 017            | 2 200                                | 5 436            | 1 900           | 4 695            | 4 000  | 9 884            |
| Quebec                  | 16 467*                           | 40 690           | 10 164                               | 25 116           | 705             | 1 742            | 20 000   | 49 421           |
| Ontario                 | 18 217                            | 45 015           | 11 210                               | 27 700           | 10              | 25               | 22 500   | 55 598           |
| Maine                   | 1 620                             | 4 003            | 200                                  | 494              | 481             | 1 189            | 2 460  | 6 079            |
| New Hampshire           | 17                                | 42               | 9                                    | 22               | —               | —                | 17   | 42               |
| Vermont                 | 38                                | 94               | 19                                   | 47               | —               | —                | 39   | 96               |
| Wisconsin               | 34                                | 84               | 85                                   | 210              | —               | —                | 10   | 25               |
| Minnesota               | 44                                | 109              | 9                                    | 22               | —               | —                | 5  | 12               |
| Michigan                | 64                                | 158              | 210                                  | 519              | —               | —                | 15   | 37               |
| Total                   | 38 802                            | 95 881           | 25 758                               | 63 649           | 3 367           | 8 320            | 49 500   | 122 316          |

\* Surveys conducted by Quebec do not record the area of current defoliation in stands with dead trees. However, some of these stands sustained defoliation in 1981 and the area of dead and dying trees has been added to the area of visible defoliation actually recorded.

In the West, defoliation of Douglas-fir and other conifers by the western spruce budworm, *C. occidentalis* Free., occurred over 1.7 million ha (4.2 million acres) and dead and dying trees were recorded within areas totalling 36 000 ha (89 000 acres). No operational spray programs were carried out in 1981. It is predicted that the area of defoliation will increase by 34 000 ha (84 000 acres) in 1982. Data on the outbreaks of the western spruce budworm are summarized by province and USDA-FS region in the following table.

| Province<br>or<br>Region**                              | Area of<br>Visible<br>Defoliation |                  | Dead and Dying<br>Trees |                  | Area of Forest<br>for 1982 |                  |
|---|-----------------------------------|------------------|-------------------------|------------------|----------------------------|------------------|
|   | (X1000<br>ha)                     | (X1000<br>acres) | (X1000<br>ha)           | (X1000<br>acres) | (X1000<br>ha)              | (X1000<br>acres) |
| British Columbia  | 21                                | 52               | —                       | —                | 21                         | 52               |
| Region 1<br>(Montana, Northern<br>Idaho, NW<br>Wyoming) | 378                               | 934              | 23                      | 57               | 398                        | 983              |
| Region 2 (Colorado,<br>Wyoming)                         | 675                               | 1 668            | 13                      | 32               | 600                        | 1 483            |
| Region 3 (Arizona,<br>New Mexico)                       | 194                               | 479              | —                       | —                | 200                        | 494              |
| Region 4 (Utah,<br>Nevada, Central<br>Idaho)            | 270                               | 667              | —                       | —                | 320                        | 791              |
| Region 6 (Oregon,<br>Washington)                        | 139                               | 344              | 0.4                     | 1.0              | 182                        | 450              |
| Total   | 1 677                             | 4 144            | 36.4                    | 90.0             | 1 721                      | 4 253            |

\*\*States affected are shown within parentheses.

In British Columbia, the two-year-cycle spruce budworm, *C. biennis* Free., caused defoliation of alpine fir and white spruce on 38 000 ha (94 000 acres) in two areas north of the western spruce budworm infestations.

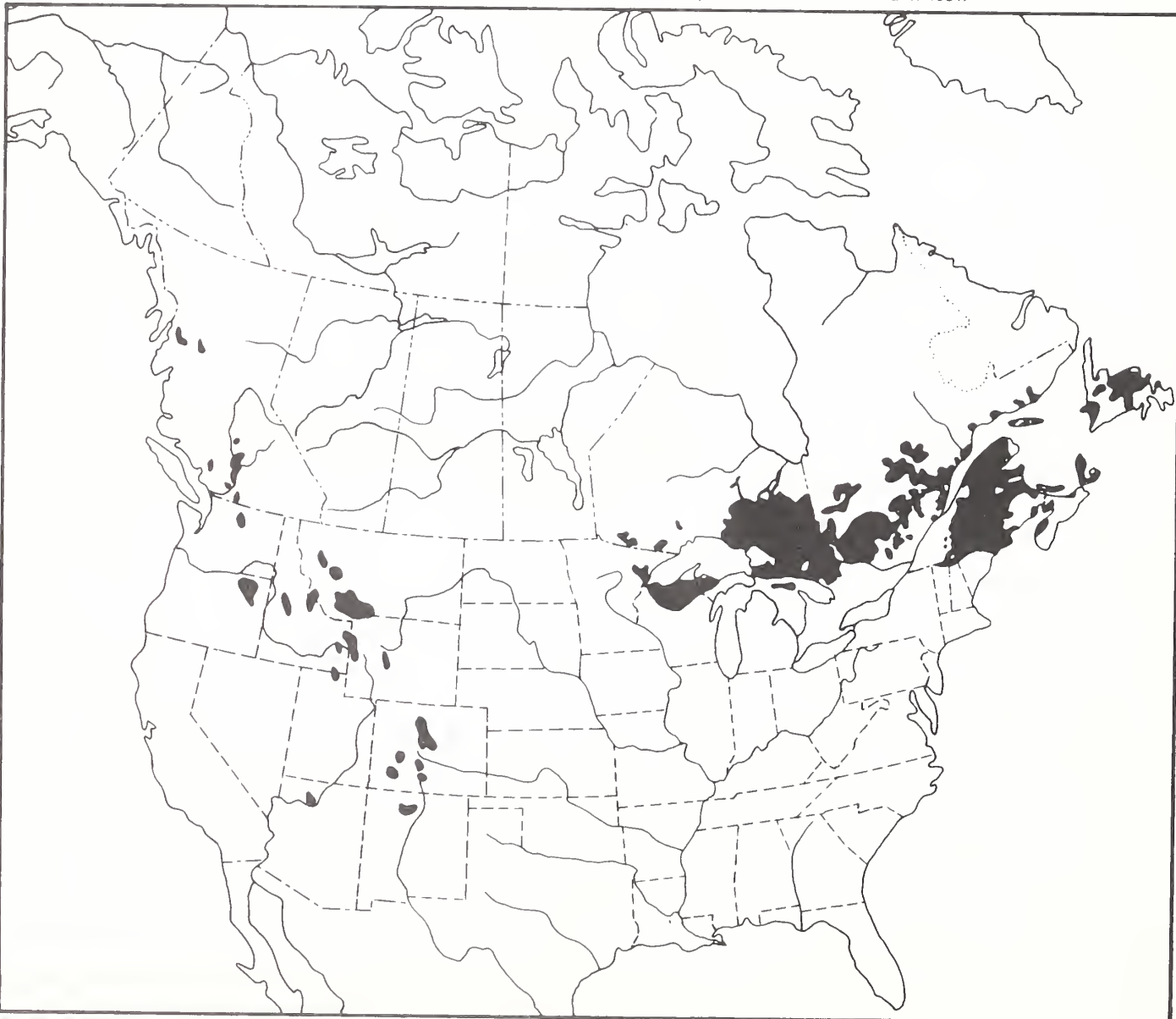
Acknowledgement is made of the information provided by forestry officials of the provinces and states concerned, the Committee on Standardization of Sampling Techniques of the Eastern Spruce Budworm Council, Forest Protection Limited, the regional offices of the USDA Forest Service and the Forest Insect and Disease Survey units of the CFS.

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Figure 3: Areas within which visible defoliation by the spruce budworm and western spruce budworm occurred in 1981.



## Tenth Annual Forest Pest Control Forum — Notice of Change of Date

Because of a conflict with the joint meeting of the Entomological Society of America, the Entomological Society of Canada, and the Entomological Society of Ontario, the dates of the Tenth Annual Forest Pest Control Forum have been changed from November 30-December 2, 1982 (as announced) to November 23-25, 1982. The organizers regret the necessity of holding the Forum during the week of the American Thanksgiving.

## CANUSA-East Working Group Meetings, October 1981

The CANUSA-East working groups met in Quebec October 20-22. Eastern Program Management extends its appreciation to the Canadian Forestry Service, especially to Andre Lavallee, of the Laurentian Forest Research Centre, for their fine contribution to a successful meeting.

The working group chairpersons presented summary reports based on precedent panel discussions, except for the Integrated Pest Management Planning and Decisionmaking working group, which did not meet in Quebec. However, the U.S. chairperson, Christine Shoemaker, reported on a joint CANUSA Spruce Budworm Modelling Meeting held in St. Paul, Minnesota, October 6-8, 1981. The Environmental Impact Working Group report was developed from a discussion of agenda items circulated before the meeting rather than from the panels.

The format of the Quebec meetings differed from previous ones because, at this stage in the Program, we wanted to review working group content from the standpoint of recent research plus operational experience in attempting to use state-of-the-art technology. Similarly, for the first time, a half-day session was spent on demonstration project reports.

## Population Monitoring Working Group

Panel Chairpersons: R. Cardé, D. Allen

Author of this Section: C.J. Sanders

Panels 1 and 2 addressed the status of adult spruce budworm trapping and problems encountered in a field trial of spruce budworm pheromone monitoring. The following items were discussed:

### A. Trap Design

Three trap designs have been considered by the group: Pherocon sticky-bottomed traps, a covered funnel trap (CFT) in which males are killed by a Vapona-type strip, and the Kendall trap, in which male moths are trapped and killed by falling into a jar of alcohol/ethylene glycol.

The Kendall jar trap gave poorest correlations in 1981 between moth catch and larval populations (Cardé), and is messy and inconvenient to use. Since it offers no advantages over the other two trap designs, the working group does not recommend it for extensive monitoring.

Comparative tests between the CFT and Pherocon traps were not as extensive as planned in 1981, because of problems in getting the traps into Canada during the Canadian mail strike. Available data from six plots in Michigan with larval densities ranging from 5 to 16 larvae/45-cm branch tip (Cardé) and five plots in New Hampshire ranging from less than 0.1 to 1 larva/45-cm branch tip (Allen) gave high correlations between larval densities and catches in CFT traps. Correlations with Pherocon traps were confounded by trap saturation at catches of 40 to 60 moths.

Problems with saturation of Pherocon traps can be overcome by using an array of traps containing lures of different potencies (Sanders did this successfully in 1981). At least nine traps must be deployed in each sample area, however, and doing this introduces complexities in interpretation. The great advantage of the CFT trap is that it does not saturate, and therefore should be appropriate for use over a wide range of densities. One problem with the trap, which occurred in 1981, was rotting of the trapped moths due to their getting wet. This problem should be solved during the winter of 1981-82 by minor design changes (to be carried out in Cardé's laboratory).

In summary, the working group concluded that the CFT has the greatest potential at this time. Its use for limited operational trials is therefore recommended for 1982. However, further comparative testing between the Pherocon ICP and the CFT trap is required for 1982.

### B. Recommended Lure

The attributes required of a lure are (1) a known release rate, to be as constant as possible over a 6-week period; and (2) low variability among lures.

The three most promising types of lure are a PVC formulation, which can be made up in most research



Figure 4: Dan Schmitt and Steve Sinclair chat about utilization of budworm killed timber.

laboratories (provided in 1981 by Canadian Forestry Service, Sault Ste. Marie), and two commercial formulations (the hollow fibers of Conrel and the laminated flakes of Hercon).

To ensure continued availability and uniformity, the working group recommends use of the commercial lures. To date, however, there are problems with both commercial products in uniformity of release rate and in variation among lures. These problems may be largely inherent in the formulation of small batches of the materials. Larger quantities should make quality control easier.

The working group recommends that CANUSA purchase from each of the two manufacturers, Conrel and Hercon, sufficient lures for the 1982 program. (This will involve more than 1,000 lures and will approximate an operational scale production.) Specifications for the lures are as follows: release rate of  $20 \text{ ng} \pm 10 \text{ ng/hour}$  at  $20^\circ\text{C}$  in a windspeed of 1.6 km/hour over a period of 1 to 6 weeks (excluding the first week to avoid the initial rapid burst of release). The companies will be expected to provide these formulations by December 31, 1981, so that they are available for independent laboratory testing. The working group also recommends that CANUSA fund two independent laboratories to carry out the evaluations (New Brunswick Research and Productivity Council and Michigan State University).

The better of the two formulations will be used for operational trials in 1982. But since both will be purchased by CANUSA, there will be no penalty to the unsuccessful manufacturer. If the two are comparable in performance, then one will be chosen for the operational trials; but comparative testing of the two will be carried out to determine their performance under field conditions.

#### C. Monitoring Pheromone Release from Lures

This involves trapping the entrained pheromone on Porapak Q, on glass, or in cold-solvent traps. Quantification of the amounts trapped has been carried out by gas-liquid chromatography or a bioluminescence assay (developed by E.A. Meighen). These methods give roughly comparable results and are similar in sensitivity, and can be used to describe the release rates of lures. Potentially the bioluminescence assay is faster, and therefore well suited to the evaluation of large numbers of samples. The working group recommends continued support of the development of this technique because quality checking of batches of lures for operational use will be an ongoing need.

#### D. Trap Deployment

Ideally traps should be deployed far enough apart to avoid interference between them. But interference occurs at low densities up to at least 40 m, and further separation is impractical. In the United States 40 m was used in 1981 and found satisfactory; in Canada 20 m has been used. For operational trials in 1982 a distance of 40 m will be used throughout.

In both the United States and Canada, clusters of five traps have been used. Other groupings will be tested to determine if fewer traps can be used, while clusters of Pherocon traps, baited with lures of different potency, will also be tested. The fact that some interference does occur up to 40 m or more from the trap should be taken into consideration when researchers make comparisons between catches with different groupings of traps.

#### E. Operational Use

The use of CFT's should be introduced into operational programs in 1982 to obtain correlations between larval populations and trap catch over a wider range of population density and stand conditions than in 1981. Tests will be initiated in Newfoundland, in addition to Michigan, New Hampshire, Vermont, Quebec, and Ontario.

The five-trap cluster is recommended, with 40 m between traps; but comparisons will be made in selected sites with other configurations as well as with Pherocon traps containing lower potency lures. The lures for the operational trials will be determined as outlined in section B above.

Estimates of larval density should be extended where possible, to establish densities of insects per hectare. This involves collecting data on tree species and size distribution, from which estimates of foliage per hectare and consequently larvae per hectare can be made.

#### Egg-Mass Sampling and Counting

Panel Chairperson: B. Montgomery

The third panel, Refinements in Egg-Mass Sampling and Counting Procedures, addressed two questions: What improvements in egg-mass counting and sampling procedures have been developed recently to improve operational egg-mass surveys? And what recommendations can be made for further improvements?

The panel expressed a great deal of interest in an automatic egg-mass counter. Some type of mechanical counter would be of great benefit to pest managers because:

1. It would reduce human counting error that is encountered when field personnel must visually search the foliage for small egg masses.
2. It would standardize counting effort within and between management units.
3. It might reduce the overall cost of egg-mass surveys.

Several things must be worked out before the implementation of an automatic egg-mass counter for surveys:

1. The operational status of the counter is presently unknown. We believe that a small-scale version of the original counter has been produced and is being tested in the West.

2. We need to know the relative accuracy of the machine and its ability to recognize and count only spruce budworm egg masses, and its ability to detect hatched egg masses and parasitized egg masses on white spruce, hemlock, and fir.

3. We need to assess the cost of training personnel to operate the machine and the maintenance needed for the counter.

The economic feasibility of employing a counter would have to be assessed by each individual survey team, but the general consensus was that the purchase of an automatic egg-mass counter could probably be justified by most groups involved in egg-mass sampling programs.

Improvements in sampling procedures are being studied by Gary Fowler and Gary Simmons from Michigan. They have developed two adjusted estimators for the correction of bias when masses are overlooked by field personnel. Data collected in Michigan are also being analyzed to determine where to sample in a tree, the size and type of sampling unit to use, how many sampling units to sample in each tree, how many trees to sample in each cluster, and how many clusters to sample in each stand to estimate egg-mass density of the stand.

Preliminary results of the Fowler and Simmons Michigan study show:

1. Considerable tree-to-tree variation;
2. No meaningful differences among directional quadrants;
3. Considerably lower and higher densities, on the average, in the lower and upper crowns respectively, compared to the entire tree;
4. Some lower and higher densities in the midcrown compared to the entire tree;
5. Considerably higher densities in white spruce trees compared to balsam fir trees in the same plot;
6. Wide stand-to-stand and year-to-year variability in the average numbers of eggs per egg mass;
7. Consistently higher mean number of eggs per egg mass on balsam fir trees than on white spruce trees in the same plot.

If sampling is to take place in one crown class, Fowler and Simmons suggest that the midcrown be sampled. However, in a given stand, sampling at midcrown can either under- or overestimate the actual density of the stand.

Fowler and Simmons have also completed a study that quantifies the differences in the characteristics of new v. old egg masses from balsam fir and white spruce. Shape appears to be the key factor in distinguishing new egg masses from those egg masses still adhering to needle surfaces for one or more years. A classification technique and photographic key have been developed.

The panel members who administer egg-mass surveys are reasonably satisfied with the sequential sampling technique developed in the 1950's by Morris. However, the panel recommended that a sequential sampling scheme be developed for white spruce, particularly when it is a major stand component. Sampling schemes for other alternate hosts are needed as well. Panelists also recommended that a sampling technique be developed to account for major differences in species composition between stands. Concern was expressed over the large sample size required when budworm populations are low.

Despite general satisfaction with current egg-mass sampling designs for balsam fir, investigators think data on egg-mass distribution would be useful (1) in establishing and clarifying certain biological relationships such as the degree of defoliation in comparison to egg-mass density, (2) for the improvement of information needed in systems simulation, and (3) for the design of sampling methods specific to the Lake States.

### **Criteria for an Operational Spruce Budworm Detection System**

Panel Chairperson: D. Kucera

Panel 4 discussed the minimum criteria that must be considered in implementing a low spruce budworm population monitoring system that will reliably indicate the beginnings of an outbreak.

The most promising technique seems to be a spruce budworm pheromone trap detection system. At low spruce budworm population densities, this could potentially replace current egg-mass counting systems, which are labor-intensive and costly.

The pheromone trap catches only spruce budworm moths and not other species of insects. It can be put out about one week before moth flight and picked up at the end of flight. If traps are placed at or near the same loci each year, a continuing monitoring system could be established.

Minimum criteria for this trap system are (1) ability to give meaningful interpretation to trap catch, (2) low cost and maintenance, (3) ease of deployment, and (4) number of traps needed to provide meaningful data.

### **Light Traps Versus Pheromone Traps**

Panel Chairperson: B. Montgomery

Panel 5 discussed the potential for light traps v. pheromone traps for monitoring low-level spruce budworm populations. A controversy revolved around apparent misconceptions concerning Gary Simmons's study in which he used light-trap time-series data. It may have been perceived that Simmons was recommending the use of light traps over pheromone traps in operational monitoring programs. He was not. Maine's permanently located light traps provided Simmons with the only available data on moth catches for an extended period of time. This was the reason for their use.

The panel was in agreement that pheromone traps are better than light traps. Light traps did provide some limited time-series data, from which Simmons demonstrated that the time-series information can be used to predict an outbreak several years before defoliation is observed. A pheromone trap system could be similarly used. Such a system would have many advantage over a light-trap system, including better coverage, ease of deployment, and additional savings in cost and labor.

Pheromone technology is a new technology, with some of the minor wrinkles still to be ironed out. For example, we have not deployed pheromone traps through time and space long enough to capture a 10- or 20-year time series of data. We recommend that the trap design and components be standardized, that traps be made generally available, and that time-series information be taken in an operational way.

There is one general caution: pheromone technology is the best tool we have for detecting changes in populations at low densities. We have many other methods of determining whether a population is medium, high, or extreme. Let us not become so infatuated with the pheromone technology that we place undue emphasis on the value of low-density detection systems.

#### Population Treatments Working Group

##### — B. t. Deposit Assessment Techniques

Panel Chairperson: P. Fast

Panel 1 addressed this question: What new techniques have been developed to aid deposit assessment in conjunction with the use of *Bacillus thuringiensis* (B.t.), and what method can be currently recommended as most practical or useful?

The session heard several reports relevant to the question, especially those by D. DuBois, USDA Forest Service, Hamden, Connecticut; and W. Smirnoff, Canadian Forestry Service, Quebec. DuBois reported on laboratory research comparing the millipore filter technique with water plates in relation to mortality. His preliminary analysis concludes:

1. There is better agreement between viable spores per  $\text{cm}^2$  (water plates) and dose applied at the different volume rates used than with viable drops per  $\text{cm}^2$  (millipore filter);
2. There is better agreement between mortality and viable spores per  $\text{cm}^2$  (water plates) than viable drops per  $\text{cm}^2$  (millipore filters).

This brief analysis of B.t. deposit indicates that millipore filters should be used cautiously and perhaps only to indicate that the spray hit or missed the target area.

Smirnoff presented a new deposit assessment technique that he concludes is amenable to field use. His report provides detailed instructions on its use. He stated that by using this method, investigators can determine the number of viable spores deposited during

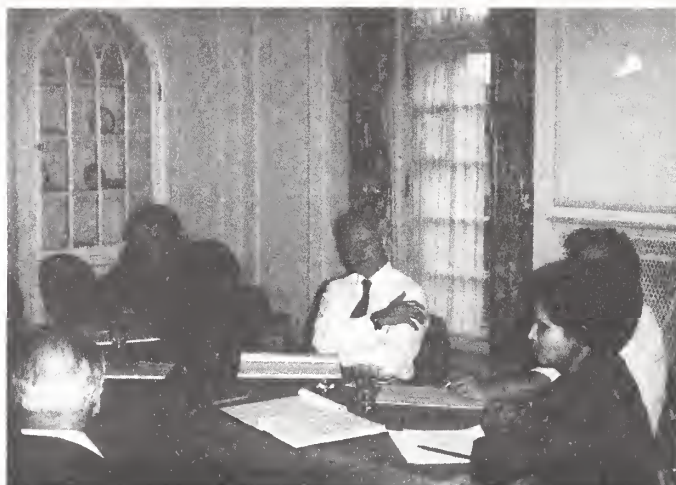


Figure 5. A roundtable discussion on spray deposit technology.

aerial application of B.t. and then determine the dispersion efficiency of the quantity dispersed and variability of the dispersion relative to swath width. His method also permits assessment of the quantity and purity of the suspension because the bacteriological assay method that was used (2.5 percent peptonized water) was chosen so as to determine all microorganisms, other than B.t., that can be present as a result of accidental contamination.

The panel also heard reports from Wiesner, Sundaram, and Himel regarding their research in deposit assessment and in-flight encapsulation. Work is going forward to study deposit on foliage either using in-flight encapsulation or incorporation of a water-soluble dye. The in-flight encapsulation results in deposits without spread factor, and without shrinkage that can be measured directly. Results show that small droplets, 20 to 30 microns, are those that impinge most effectively on spruce needles. Drops deposited on cards were larger and of different density from that on needles. Water-soluble dyes can also be used to gather the same information.

#### Improved Aerial Application Techniques

Panel Chairperson: A. Sundaram

Panel 3 discussed the question: What is the status of development of improved aerial application techniques (chemical and/or biological)?

Sundaram started the meeting with a brief overview of the major components relating to spray delivery systems. These include the following broad subject areas:

1. formulation technology
2. atomization characteristics
3. release strategies
4. deposition characteristics
5. droplet target interaction (biological interface)
6. role of meteorology.

With regard to chemical insecticides, the panel believes that further research is of high priority to investigate budworm behavior, and behavioral changes relative to the plant-host types and pesticide treatment, and the postapplication distribution and redistribution of pesticide within the microhabitat.

Because of the tremendous gap that exists in spray delivery systems between chemical and biological insecticides, the panel made these recommendations:

1. Use of Kromkote cards is only of limited application for measuring deposit for biologicals. The millipore system is not adequate and should be combined with spore counting systems to get a more realistic picture of the deposit activity. Development of crystal quantification should also be undertaken simultaneously.

2. Use of spray physics research data generated from chemical insecticide systems should not be directly applied to biological insecticides. This area of research is considered of immediate high priority for biological systems before any quantitative relationships can be considered.

3. When using a B.t. formulation, researchers should undertake droplet and counting studies for needle deposits. These should be followed up by simultaneous spore counting, crystal assessment, and bioassay techniques to optimize droplet density and droplet size spectrum on needles.

4. Further research is also needed to investigate budworm behavior and behavioral changes relative to plant-host types and insecticide treatment. Distribution and redistribution of the pesticide within the microhabitat should also be undertaken.

### **Pheromones for Spruce Budworm Control**

Panel Chairperson: C.J. Wiesner

The panel reported on four major experiments: male annihilation in cages (C. Wiesner), mating disruption—Machias, Maine (J.B. Dimond), mating disruption—Ontario (C.J. Sanders), and mating disruption in cages (W.B. Seabrook).



Figure 6: Nick Crookston, visiting from CANUSA-West, compares eastern and western approaches to insect modelling with Pat Shea.

In three of the four cases, the results were inconclusive, while the Seabrook cage experiments showed a promising dosage-dependent disruption. The consensus of the panel was that there are major gaps in our basic understanding of pheromone-mediated budworm behavior. In addition, the panel agreed that current biological assessment methods are inadequate. In particular, methods for random sampling of female moths and differentiation between resident and migrant females are crucial tools that need improvement. Lacking such improvement, the evaluators of future trials may well face the same problems as in the past.

The panel said it needed more time to discuss these matters in detail. It was suggested that the panel members should meet again or at least communicate further and draw up a more detailed position statement.

The panel made these recommendations:

1. Further investigation of basic budworm behavior should be stressed, specifically (1) influence of minor pheromone components on close-range behavior, and (2) influence of point-source distribution and release rate on behavior.

2. Validation and reevaluation of available biological assessment techniques should be supported, e.g., egg-mass density, tree washing, female trapping, and population labelling.

### **Environmental Impacts**

Panel Chairpersons: Joan Trial, Peter Kingsbury

Author of this Section: D.C. Eidt

The participants were primarily oriented toward the aquatic environment; thus most discussion was concerned with aquatic impacts.

The session consisted mainly of presentation and discussions of results of a study on the comparative effects of aminocarb formulation (1.4 OSC) and fenitrothion oil formulation (Cyclosol 63 and 585 diluent oil) by Andre Ahern of Bioconseil, Inc. (done under contract to Ministère d'Énergie et Ressources du Québec). Ahern is the first person to define a threshold for an impact of aminocarb on aquatic invertebrates by showing that drift was induced by concentrations of 30 micrograms/L or more. He demonstrated a relationship between the effects of fenitrothion (ai) and aminocarb (ai) on aquatic invertebrates: it takes approximately twice the concentration of aminocarb as of fenitrothion to have the same toxic effect on aquatic invertebrates. This gives a broad margin of safety for aminocarb, which is normally applied at one-third the rate of fenitrothion. Ahern established a matrix of sensitivity of organisms to the insecticide based on mortality of indicator genera and the total community diversity. Using this information, he described how aquatic insect monitoring could be set up using drift nets on forest streams.

Gilles Gaboury, of Ministère d'Énergie et Ressources, elaborated on the practical application of the method for monitoring in Quebec, where it might be more necessary than elsewhere because Quebec uses large aircraft whose spray equipment can be controlled only to avoid spraying the larger streams and lakes. Given their manpower resources, they had opted for a water chemistry survey.

Doug Eidt reported on work by himself, Al Sosiak of Montreal Engineering, and Vic Mallet of Université de Moncton on partitioning of fenitrothion in a stream. They sprayed a section of each of two streams and followed the fate in various compartments of emulsifiable concentrate (EC) in one stream and 585 oil-based formulation in another. They found that fenitrothion from the oil-based formulation moved to the bottom of the water column as quickly as it did from the EC formulation, i.e., within 70 m of where it was applied. Also, in 1-litre samples of filtered water, on the order of half the insecticide was in the residue, which was a very small quantity on a 0.45-micron millipore filter. Some organisms took up large quantities of fenitrothion, notably a liverwort at a bioconcentration of 500 to 700 X (wet weight). Another liverwort, though, did not take up as much. The phenomenon is not explained.

Mac Hunter, University of Maine at Orono, described effects on ducklings in ponds sprayed with carbaryl, where arthropod biomass was reduced. The ducklings made reduced daily weight gains for a period after spraying.

Jon Stanley, UMO and Maine Cooperative Fisheries Unit, remarked that fish weight gains do not seem to follow the model of Symons, which predicted a detectable reduction in salmonid growth if benthos standing crop is reduced by more than 65 percent. Stanley found immediate weight gains, as a result of engorgement on spray-induced benthos drift, more than compensated for reduced gains that might result from temporary benthos depletion.

Other UMO researchers described methodologies, such as measurement of leaf detritus decomposition in streams, measurement of acetylcholinesterase (AChE) inhibition by a simple field procedure, and a linear index of food electivity in studying foraging behavior in fish. Bioconseil, Inc. has used respiration of microorganisms on leaf litter from contaminated and noncontaminated streams to evaluate the impact of aminocarb on decomposition.

Future plans were discussed in general terms, and panelists offered to review one another's research proposals.

### **Outbreak Causes and Habitat Manipulation**

Author of this and subsequent Sections: D. Schmitt  
A. Availability and suitability of hazard-rating systems for forest managers.

Panelists noted that a comprehensive review of forest insect hazard rating could be found in "Hazard-Rating Systems in Forest Insect Pest Management: Symposium Proceedings," Gen. Tech. Rep. WO-27, USDA Forest Service. The symposium presents methods but not a generally useful definition of hazard rating, for the methods reflect a perception of the R & D required for regional situations. Since we expect foresters as well as forest pest managers to find hazard-rating systems useful, what is and what is not a hazard-rating system becomes important.

Forest entomologists employ the terms "susceptibility" and "vulnerability" in constructing hazard-rating definitions. Dictionary definitions of these words do not convey the connotation attached to them by entomologists. Consequently hazard rating defined in terms of susceptibility and vulnerability is not meaningful to foresters.

The panel essentially agreed that susceptibility means the probability (or risk) that a forest will be attacked by spruce budworm, and vulnerability is the estimate of damage resulting from attack. Since damage is a relative word, most foresters prefer to substitute mortality or growth loss (but see discussion on growth loss). After discussion, most panelists agreed that the phrase "hazard rating," for operational use, should include only the concept of vulnerability. A simple operational definition of hazard rating for spruce budworm might be "a method of ranking stands or compartments according to estimated mortality (and/or growth loss) following spruce budworm attack."

The panel next considered existing and potential uses of hazard-rating systems and what was available. Use sorted out into two broad classes: (1) planning aerial insecticide operations against budworm, and (2) planning cutting operations.

Forest pest managers' use of hazard rating in planning population treatment is well developed in Maine, New Brunswick, and Quebec. The principal components and (1) mapping the infested area, (2) determining forest conditions within the infested area (current mortality and defoliation, and past defoliation levels), and (3) determining current population levels and next year's projected population level. Areas within the protection zone are ranked according to a weighted sum of scores for each of the components contributing to (2) and (3). These rankings, transferred to maps, provide the first cut at defining suppression blocks. Subsequent adjustments are almost always made on the basis of more recent population information and decisions on the kind of insecticide and mode of delivery.

The Eastern Spruce Budworm Council has appointed a committee chaired by Louis Dorais to evaluate the possibilities of standardizing survey techniques to acquire data for constructing the annual hazard rating. An interim report describing the features of the three

hazard-rating systems (mentioned above) has been distributed, and the Council will publish a comprehensive analysis based on the Committee's work.

A modification of the Maine hazard rating, developed by the Green Wood Project, has been used to guide salvage and presalvage operations by cooperators. Application of the modification has significantly reduced the areas sprayed on the project. The Maine ratings can be displayed on computer maps with the existing road net—part of a University of Maine project to improve the efficacy of salvage operations. It should be noted that in all of these applications the annual hazard rating for suppression is used.

Batzer and Hastings developed a hazard-rating system for Minnesota ("How to rate spruce-fir vulnerability to budworm in Minnesota," North Central Forest Experiment Station, USDA Forest Service). Forest Pest Management (U.S.) is using this system in a Lake States demonstration project. Since the Batzer-Hastings format is in a convenient tabular form, Greentree, Inc., also uses it in the development of a program for a TI-59 hand calculator to analyze economic alternatives for properties subject to budworm attack. (Robert Marty described this project in the demonstration review session.)

A University of Michigan team is developing a hazard-rating system for the Upper Peninsula. Since their approach employs an extensive plot system over a wide range of stand conditions, this system may be particularly useful in guiding cutting operations to reduce hazard. In addition the team is evaluating the data base to develop efficient hazard survey procedures (see Damage Assessment).

After reviewing available hazard-rating systems, the panel characterized systems by use and time frame. Suppression planning, a short-term application, requires population and stand condition information. If good stand condition information is incorporated, the suppression ratings system can be used for short-term salvage planning in case of an outbreak. Long-term uses include planning salvage and presalvage operations after an outbreak, and guiding cutting operations in a prevention mode. The panelists believed that over the long term, hazard rating should influence forest management planning in the spruce-fir region. Of course, foresters (see Outbreak Causes and Habitat Manipulation) would be unlikely to alter cutting methods to reduce hazard if they felt that by doing so they would jeopardize cost/production goals. However, even if managers are willing to accept some mortality risks in the event of attack, the routine availability of an updated hazard rating for their stands would make possible smooth transitions to emergency salvage and presalvage operations.

Regarding how a hazard-rating system should be made available and who should use it, panelists responded that format depends on the intended application of the system and the user. But they tended to

agree that the user was a forester or forest technician in a field or office/field setting (implying that the user collects and processes the data).

This seems to be in accord with the lack of discussion on the possibility of a central planning group within a forest management organization as a "user" and the dismissal, at least for the present, of developing hazard-rating models. (Current approaches to hazard rating, however, involve multivariate formulations, which lend themselves to just this form of application.) Preferred delivery vehicles are "how-to" publications for training purposes and technical and scientific publications for professionals and scientists. Graphic and tabular presentations are particularly desirable for training purposes.

Stand composition (proportion of spruce-fir), stand age, and density are the principal parameters of long- and short-term hazard-rating systems. Discussing hazard-rating parameters, the panel also mentioned "other" tree attributes, characteristics of budworm and associated parasite populations, and economic conditions as important. Investigations in comparative evaluations of mortality by species in Maine in mixed wood and pure stands were not mentioned. Any long-term hazard rating developed for Maine would have to consider these results. However, it was noted that different regions would probably require different hazard-rating systems. For example, stocking of spruce and fir is on the average higher in the Maritimes than in the Lake States.

#### B. Variables Measured Over Time

The panel felt that normal 5- to 10-year inventory cycles would accommodate the need for dating hazard ratings. However, they stated that acquiring hazard-rating data was particularly important in the pole/mature stages of forest development because hazard rating is particularly sensitive to stand and insect population changes during these developmental stages. Panelists also noted that population increases can be detected before significant defoliation (see Population Monitoring) and that such signals should trigger hazard rating updates.

#### C. Site Quality and Stress

A panelist (Shortle) reported that cambial electrical resistance (CER) readings from spruce and fir trees could be sorted into three classes: a low range, indicating excellent recent growth performance; a normal range; and a high CER range, indicating substantially below-average recent growth performance. Sampling on a small plot basis showed that by averaging tree readings it was possible to obtain a crude estimate of recent growth performance in the area (a measure of site quality). Since trained operators can obtain a CER reading from a tree in 2 or 3 minutes, it is clearly possible the technique can be employed in a survey mode. Previous work showed that CER readings are closely related to

defoliation levels of infested trees. We have yet to establish whether plot evaluations of site quality are related to mortality. Recent publications on this set of investigations can be obtained from the authors (Shortle et al. Forestry Sciences Laboratory, Concord-Mast Road, P.O. Box 640, Durham, NH 03824) or from CANUSA-East management.

The panelists also reported that hardwood investigations had shown that if a tree exceeded the normal CER range, regardless of the current status of the tree, death would occur within 3 to 5 years. Whether such a relationship holds for spruce-fir is unknown.

Research on the relationship between Thornwaite potential evaporation (PE), spruce-fir stocking, and budworm-caused mortality was not reported as the data are still being analyzed. However, the principal investigator (Heikkinen) did report that for balsam fir a modified stem analysis technique based on age 10 determined at 3 to 4 m (10 to 14 feet) and subsequent height growth was a remarkably good indicator of balsam-fir site quality.

There also seems to be a relationship between the level of foliar nutrients, N, Mn, and K, and a measure of site quality—drainage. All three are higher on well-drained sites. The same investigators (Czapowskyj, Allen et al.) also collected budworm fecundity data to investigate the possibility of a linkage between foliar quality and fecundity. The implied relation between foliar nutrient levels and moisture is of interest because published Canadian work on a western shrub species reports that a useful relation exists between Shigometer (CER) readings and Scholander pressure bomb determinations. The pressure bomb measures current internal plant moisture stress.

Although the panel was confident that a potentially useful relationship exists between stress and subsequent mortality following budworm attack, they ruled out any possibility of using stress information in short-term hazard rating because epidemic population would negate its value: trees repeatedly defoliated will die. Stress information could be usefully included in long-term hazard rating, but the panel concluded that attempts to do so would be premature pending further research.

#### D. Insect and Host Quality

The panel was unable to determine whether the level of budworm populations can be related to host quality. The range of larval growth rates on the more common hosts appears to be from 10 to 30 percent. Larval responses to host quality of this magnitude could be expected to affect fecundity (see Site Quality and Stress). The relative levels of genetic and environmental components of fecundity are not known now. Previously published Canadian research (Miller, Blais) shows that back feeding on balsam fir reduces fecundity. In 1962

I.M. Campbell postulated two X-chromosome variants that affected larval size and fecundity differences in budworm (abstract 323 in *Spruce Budworms Bibliography*). A recent publication on population biologies suggests that theoreticians concerned with cyclic or "chaotic" populations feel that fecundity-larval survival relations, operating in a negative feedback mode, may be a potent force in population biology.

Budworm development is markedly different on balsam fir and white spruce, according to the panel. There tend to be more egg masses and faster larval development on white spruce. Also, upper crown temperatures during active periods are higher in white spruce, as is foliar moisture content. By contrast, egg-mass size is larger and larval survival, foliar N, and caloric content are higher in balsam fir.

Research by panel members has shown that high N levels result in larger larvae that consume less foliage. As previously noted (see Site Quality and Stress), N may vary with site conditions, particularly moisture. In a Nova Scotia study, Peine (see Damage Assessment) showed that N, P, and K content of current fir needles varied with defoliation levels, tending to increase with increased defoliation. Magnesium and Ca were relatively unaffected.

Past research rules out carbohydrates as a significant dietary requirement, but carbohydrates, terpenes, etc., may be potent stimulators of feeding behavior. Hunger is always a proximate cause of feeding, but in most animals (including man) feeding can be stimulated against a hunger gradient. Feeding behavior does not necessarily imply consumption, but in the case of grazing insects probably always implies wasting of host tissue.

Foliage nutrients by species (white spruce and balsam fir—apparently little is known about red spruce) do not appear to vary significantly across regions, but pupal weights and genetic population indices (based on isozyme analyses) do. The panel stated that, as of now, pupal parameters are the best indicators of host quality. It is known, for example, that pupal weight is related to fecundity (Miller). But pupal weights are higher on white spruce than fir in Quebec, and the reverse occurs in Minnesota and Connecticut. Also populations differ genetically by geographic region.

While it may be some time before we understand budworm/host interactions, several points are worth noting. Population quality in a genetic sense varies geographically. Local variation probably occurs as well. There are definite larval population reactions to some foliar components in terms of development, survival, and fecundity. Nitrogen varies with site conditions, and host forests react to grazing pressure (1) by changes in current foliar composition; (2) as a result of defoliation, by offering less desirable oviposition sites; and

(3) through mortality, changing composition which in turn alters quantity and quality of host tissues. The increasing time scale, in budworm generations, of this sequence of events provides a mechanism for accomplishing substantial changes in quality (and probably numbers) of budworm populations.

The detailed analysis of the Quebec outbreak by Hardy, involving simultaneous irruptions in widely separated habitats with common but seemingly unlikely "budworm" vegetated conditions, can accommodate cascading population development with different but increasing reinforcement levels as suggested above. From an operational standpoint, relating populations to habitat can identify the setting for population monitoring efforts that will provide forest and forest pest managers ample time to evaluate and implement control measures.

### **Silvicultural Approaches to Reduce Hazard**

In the simplest terms forest management is the result of decisions to remove or not to remove vegetation. These decisions are determined by production goals and constrained by costs. Hazard-rating guides (long-term) imply that the risk of mortality in the event of a budworm attack can be reduced in medium- to high-hazard conditions by appropriate adjustments in composition, stocking, or both. The panel was asked to identify the operational constraints affecting recommendations derived from hazard-rating guides. The panel first considered the opportunities presented by precommercial thinning.

Precommercial thinning is an investment since the returns are deferred: the operation cost is the investment. The panel stated that current growth rate of natural spruce-fir stands of about half a cord per acre could be doubled. They believe that thinning (and under some circumstances precommercial thinning) is an attractive investment opportunity. One panelist (Frank) provided data from a thinning study in support of these expectations. By making some simple but realistic assumptions, one can generate growth on treated plots ranging from 0.6 cord/acre/year (simple row thinning) to 0.97 cord/acre/year (approximately  $8 \times 8$  spacing). Since the study is only in its fifth year and probably far short of full response, it is easy to see why foresters are bullish on the growth potential of the spruce-fir type.

The balsam fir component of mixed species stands will contribute greatly to the achievement of such production goals. However, to the extent that reducing hazard compromises composition and stocking targets, there will be a tendency to forgo protection (i.e., accept risk of future budworm mortality). Moreover, the larger the interval between the operation (as in precommercial thinning) and capturing the investment return, the better the opportunity to hedge the risk by intermediate

(commercial) cuttings to reduce hazard. In brief, foresters agree with the entomologist in a previous panel that hazard-rating guides will be used most when stands reach commercial size.

Next the panel was asked what minimum volume constraints affect cutting decisions. The answer was 5 to 10 cords/acre, but deviation was common. One panelist pointed out that isolated patches of softwood in mixed wood or hardwood forests would not likely be cut. Location with respect to scheduled cuts, accessibility, and other factors were cited as circumstances that could outdate minimum volume consideration. Whatever the reason, it is clear that hazard reduction alone would rarely provide sufficient rationale for a cut decision.

Since implementation of hazard-rating guides often involves partial cutting, the panel cited the following operational constraints that affect partial cutting decisions:

1. Windthrow—(treated separately below),
2. Size of the wood. As previously indicated, only high investment potential justifies precommercial operations. In most situations the operation is expected to pay for itself. The size of the material (and its distribution) determines production efficiency, a key profitability factor.
3. Stand history. Past cutting history or its absence determines current stand conditions, which affect not only partial cut decisions but how they could be implemented. For example at one extreme, natural heavily stocked stands could require removal of a relatively small percentage (probably 30 percent or less) of the basal area, most of which would come from the intermediate crown classes. At the other extreme, severely high graded stands with poor stocking in low-quality residuals would likely be clearcut if cut at all.
4. Composition.
5. Season and associated weather. These factors affect productivity. Productivity for partial cutting can be maintained at reasonable levels in late summer or early fall. One panelist (Cassese) stated that open winters provided an exceptional opportunity for treating stands requiring partial cutting because of improved equipment mobility and reduction in delimbing requirements (fir).
6. Equipment. Mechanical harvesting and transport equipment are often not well adapted to partial cutting. In some cases amortization of high purchase costs requires operation at near optimum production rates more or less continuously.
7. Labor. The nature of management-labor agreements, including but not restricted to procedures for determining individual or unit pay, can limit partial cut options for stand treatment.
8. Soils and terrain. Unfavorable soils and terrain, individually or in combination, can make areas functionally inaccessible.

If it were possible to single out a factor most affecting partial cut decisions, it would be concerns about excessive windthrow. Spruce-fir is one of the most windthrow-sensitive formations, probably because the species are shallow-rooted and are typically found in subarctic or extreme continental climates in which sudden upward temperature shifts result in liquefaction of the forest floor while the basement remains frozen (e.g., winter chinooks and typical spring breakup). Although there is an extensive European literature, and some North American, on minimizing windthrow in mountainous terrain, there are no guidelines for minimizing windthrow in the second-largest boreal forest in the world.

Areas in which stands are known to have suffered excessive windthrow and breakage prior to harvest scheduling are not candidates for partial cutting. Inventory and marking crews are instructed to record this information in the normal course of their work (Cassese).

Partial cutting is risky in heavily stocked softwood stands not previously cut.

Windthrow risks following partial cutting are minimal in mixed wood stands if the hardwood component (usually not cut) is well distributed (maximum probability in summer).

Short (usually means young) stands are at less risk than tall ones. (Short and tall were not defined, but break point is probably 10 to 12 m [35 to 40 feet]).

There was not enough time to discuss characteristics contributing to windfirmness in residual trees. It was mentioned, however, that full-crown trees are more wind resistant than trees with small or spindly crowns.

In concluding this topic, the panel was asked to evaluate windthrow experience following strip and partial cutting. Panelists agreed that windthrow in strip and partial cuts had been a serious problem. One of the panelists (Frank) had studied windthrow patterns on strip cutting for 10 years. Some of his information, based on over 300 down trees, is shown in the table below.

|                | Percentage of windthrow |                      |            |
|----------------|-------------------------|----------------------|------------|
|                | Balsam Fir<br>86        | Red Spruce<br>9      | Other<br>5 |
| Tree Condition | Uprooted<br>33          | Broken<br>67         |            |
|                | Decayed<br>64           | Sound<br>36          |            |
|                | Merchantable<br>71      | Unmerchantable<br>29 |            |
| Location       | Leeward<br>53           | Windward<br>47       |            |

In this study most of the windthrow occurred in the first 6 years, and Frank estimated that two-thirds of it would have been lost anyhow. If this is true, the actual volume lost on edges because of wind would be 0.6 to 1 m (2 to 3 feet)/year/200 m (10 chains) of edge. A complete presentation and interpretation of this unusual data set will be published soon.

Relating harvest systems to stand conditions was too complex to be summarized, and the prescriptions in the *Spruce-Fir Guide* (USDA Forest Service, Gen. Tech. Rep. NE-6, 1973, available from 370 Reed Rd., Broomall, PA 19008) provide usual guides for most of the typical stand conditions found in the spruce-fir region of Maine. However, the panelists did list some of the most important factors for deciding what harvest system to use. These appear in the table below. Depending on the situation, any one factor could be the most important in making a decision.

| Composition              |              | Advanced<br>Regeneration                                 | Stand Vigor<br>and Site                            |
|--------------------------|--------------|--|--|
| Clearcut                 | 50% + fir    | Ample  | Poor, dense<br>stocking                            |
| Stripcut <sup>1</sup>    | " "          | Moderate   | Good, windfirm                                     |
| Shelterwood <sup>1</sup> | 40% + spruce | Poor or poor<br>in spruce                                | Good, windfirm                                     |
| Selection                | 50% + spruce | Ample, dis-<br>tributed over<br>range of site<br>classes | Moderate,<br>windfirm,<br>appropriate<br>structure |

<sup>1</sup>Budworm protection essential

Managers considered hazard rating (i.e., potential mortality) more important than the amount or distribution of current mortality when scheduling salvage operations. Since high fir content results in high hazard rating, it can be assumed that most presalvage and salvage operations are clearcuts (see table above). The other factors that influence the conduct of salvage operations are those common to scheduling any set of harvest cuts, with accessibility ranking as the most important.

**Factors Affecting Utilization and Marketing of Balsam Fir**

Recent research (Basham) suggests that in balsam fir there are three general patterns of sap stain and rot which differ in development rates. Since the amount of sap rot determines the suitability for pulp and the amount of stain determines the suitability for lumber, these patterns relate to differences in the salvage life of balsam fir. Moreover, it is highly probable that the occurrence of these patterns is associated with regional climates.

Currently managers salvage stands within 1 year of death or not at all. This practice is probably too conservative. Depending upon pattern, salvage pulpwood can be usefully harvested up to 3 years after death and, in the best pattern, sawtimber up to 5 years. The Shigo-meter, an instrument ideally suited for rapid assessment of decay pattern, can be used to determine local patterns. The manager can then assess the probable life of fir on his operating units.

Whether a stand should be salvaged, however, is an entirely different question. In most circumstances salvage operations will be less profitable than normal operations in like stands. Not only will less usable wood be recovered, but productivity on gross volume basis will fall off. The panelists agreed, for example, that mechanized felling and bunching were unsuited for most salvage operations because of excessive breakage. Salvage operations also increased safety precautions, and sometimes, special crew training. More important, markets must exist before scheduling salvage operations.

A survey of lumber yards in St. Paul by one of the panelists (Sinclair) disclosed that yard managers perceived Douglas-fir as the best selling species and priced it accordingly. Eastern pine species were ranked marginally better than balsam-fir, and eastern spruce was a distant last. Balsam-fir studs were not readily available, although customer acceptance was good.

Customer acceptance was predictable when based on wood quality research and testing properties closer to operational use characteristics than those commonly conducted in timber physics research. Lumber grade yield should please mill managers as well, because it is relatively good in the better grades but declines drastically if trees are dead more than a year before processing (but see discussion on patterns). Structural properties of dimension material from dead trees also decline, but these changes are relatively slight compared to drops in grade recovery.

Kraft pulp from trees dead 1 year and green trees did not differ appreciably in strength properties, but the dead material requires longer cooking schedules. Similar results were obtained from TMP pulps except that the furnish produced from dead material had slightly different optical properties.

Wafer- and flakeboard are new market opportunities for balsam fir. The premier species in the Lake States used for this purpose is aspen. Sinclair's research indicates that in the laboratory and from pilot tests with a cooperator, particleboard made from balsam fir, dead or alive, meets all the required standards, but the amount of fines increases as time since death increases (up to 2 years). Interestingly, the internal bond strength of panels prepared from dead material was better than that from green material. No different problems in kind or degree were encountered in processing fir compared to aspen (fines excepted).

Precise estimates cannot yet be made of the mortality expected in merchantable trees in the near future, but it may average 25 percent with considerably higher losses in some areas. In general market conditions, if the choice is to purchase wood outside the operational area, the temporal availability of a salvage resource becomes important if it can be exploited without major changes in processing procedures or declines in product quality. CANUSA utilization research to date implies that this condition can be met, provided foresters correctly identify stands for salvage.

The suitability of balsam fir for particleboard is a major new market opportunity that could significantly enhance the value of the species and make salvage attractive, where it is possible. There is as yet no evidence of erroneous perceptions concerning the quality of balsam fir for dimension lumber along the East Coast, although skepticism concerning the utility of salvage among stumpage purchasers and landowners does exist. It is important that good information on product quality from salvage material be distributed. Past experience in salvage programs quickly reaffirms an unpleasant facet of human nature—the knowing will always exploit the ignorant.

### **Relation of Parasite and Predator Populations to Habitat Conditions**

The panel focused on birds and parasites and whether information relating their populations to forest conditions could be usefully incorporated in hazard-rating systems. The answer was no—at least until the net of interrelations is better understood than at present.

Insectivorous bird guilds sort out according to stand structure and composition. Pure even-aged fir stands, pole-size or larger, do not provide suitable bird habitat for many budworm-feeding species. Planned forest management maintaining balanced size classes, spatially distributed or within stands, will result in the diversity required for a full range of insectivore guilds. There is little information, however, on food preference, search habits, satiation levels, switching behavior, etc., although CANUSA-West is beginning to gather some interesting data that can be related to budworm population levels.

The parasitoid complex is also influenced by stand structure. Given the relatively short budworm larval cycle, some larval parasites would almost certainly require alternate hosts. What they are is not known. Although there has been research on the population dynamics of major budworm parasites, the focus has been dynamics and not the ecofactors influencing dynamics. One panelist (Nyrop), for example, reported that *Glypta fumiferanae* adults were far more sensitive to ambient temperature than habitat conditions, and that nectar feeding did not occur or was insignificant.

The panel also commented that the linkages between parasite levels, stand condition, and hazard rating, if they exist, would be indirect. If hazard rating estimates mortality, as it does in the restricted definition (see Hazard Rating), then its magnitude is directly determined by budworm population levels and relative availability of preferred species. The latter is an independent component of hazard rating. All other habitat-related effects are expressed in terms of postulated impact on the budworm population, which is not a component of long-term hazard rating. One of the most vexing problems in budworm dynamics is how well budworm populations are buffered against predation.

### Damage Assessment

A. The panel on mortality assessment addressed six topics. The first concerned whether a capability existed to use satellite imagery for regional mortality assessment. For the short term the panel argued that satellite imagery would not be suitable for regional mortality assessment, principally because there may be a 1- to 3-year time gap before new imagery becomes available, resolution of available imagery is not good enough, and most forestry organizations lack a satellite imagery processing capability and the investment funds to obtain it. One panelist noted that when and if LANDSAT D is launched, there should be dramatic improvement in resolution. Currently, optical bar and other high-altitude photo techniques are far more promising for mortality assessment and other forestry purposes than satellite imagery. The USDA Forest Service pilot tested optical bar high-altitude technology on a mountain pine beetle outbreak with good results.

Next, the panel reviewed mortality information from Maine and the Maritimes. Lawrence and Houseweart summarized data from Maine in a report (Impact of the Spruce Budworm in the Maine Spruce-Fir Region 1975-1979 period, University of Maine, Miscellaneous Report 250, 1981) that is available from Northeastern Area State and Private Forestry, USDA Forest Service, 370 Reed Road, Broomall, PA 19008. An intensive study of mortality is underway on Cape Breton. Early results were reported by Piene in *Forest Science* (26:665-673). Results of a western Quebec mortality assessment study following population collapse were reported at the Buffalo working group meetings and will soon appear in the *Canadian Journal of Forestry Research* (Blais). Early results of a 1979 mortality assessment study in Laurentian Park were also reported (Blais). New Brunswick completed damage surveys in 1979 (freehold lands) and 1980 (extended to all lands), and the results are expected to be available soon. Results from Newfoundland were not available, although an extensive plot system was established, and the first reports should be appearing soon.

The following table summarizes the information.

| Species | Percentage Mortality |                   |                             |
|---------|----------------------|-------------------|-----------------------------|
|         | Maine<br>(Vol.)      | Quebec<br>(Stems) | N.B. <sup>1</sup><br>(Vol.) |
| Fir     | 4.5                  | 37                | 19                          |
| Spruce  | 0.2                  | —                 | 8                           |

Cape Breton  
(Stems)

<sup>1</sup>Not reported at meeting; estimated figures believed to be in the ballpark.

The figures above are not useful for a comparative analysis of budworm mortality over regions nor for a given region without consulting the specific reports. What the tabulation does illustrate is an apparent agreement that expressing mortality information in percentages is useful, and that there is no agreement on how mortality should be expressed (stems, volume, etc.). If it were desirable to make an eastern North America assessment of budworm mortality from surveys and investigations in place, mortality data are best expressed as cubic meters per hectare. Although the various investigations were undertaken for different purposes, the data taken can provide an estimate of volume in this form. It would be helpful if mortality were expressed in this fashion where it has not been done already.

The panel next considered whether Canadian Forestry Institute (CFI) techniques using photo interpretation of permanent plots could be applied to damage assessment. One panelist (Olson) wrote that it was possible but noted the following practical difficulties: (1) current stratification procedures for sample plot location do not include hazard rating and could result in serious underestimates, especially if mortality were scattered; (2) normal CFI procedures require that sample plots be treated as the surrounding area so that presalvage and salvage cutting could result in underestimates of mortality; (3) estimates derived from photo plots could be affected by accuracy of species determination (spruce v. fir).

There was little discussion on how mortality information should be transmitted to users. In Olson's opinion (addressing the U.S. situation) the USDA Forest Service should digest the available information to a 5- or 6-page technical report for distribution to State agencies, Forest Service personnel, and industry. The State forest pest managers, with the help of extension specialists, would condense this information (perhaps supplemented by additional local information) into one or more subregional pamphlets and/or news releases for distribution to nonindustrial landowners.

B. One approach to mortality projection is incorporated in hazard rating. Blais reported on a cooperative Provincial effort to develop a vulnerability index. Because forest conditions in the Provinces differ, there are variations in the final form of the index. But its basic components are (1) merchantable volume of fir and white

spruce, (2) maturity of fir, (3) merchantable volume of black and red spruce, and (4) climate. Details on construction of the vulnerability index can be had from Blais at the Laurentian Forest Research Centre. He reported that the index had already been experimentally validated in part on survey units with good correspondence between expected and observed impact.

Currently the definitive publication on patterns of budworm mortality is MacLean's exhaustive 1980 analysis of data from eastern Canada and United States (*Forestry Chronicle* 56:213-221). In general, mature stands of balsam fir under continuous attack will suffer close to 100-percent mortality. Projection for younger age classes of fir is less certain; there are insufficient data on spruce. Consequently stand condition (varying composition and size distribution), with the exception of mature fir stands, is uncertainly related to mortality at local levels and where fluctuations in budworm populations occur.

Where good forest inventory information is available, useful short-term mortality projections can be made (Seegrist, in press). A major advantage of the technique is that natural mortality is accounted for. In brief, loss is defined as the difference between the expected stand inventory based on the projection of the most recent standing inventory (measured) before the budworm attack and the observed standing inventory at the end of the measurement cycle. Although the inventory cycle in Maine is complete, the data are not yet available. But, by taking advantage of the extensive data base of the Maine Growth Impact Study, Seegrist was able to demonstrate that budworm-caused mortality in Maine had increased by a factor of 2.5 in recent years.

There is a pattern that seems to be emerging, partially confirmed by Canadian information from continuously monitored plots. Mortality is initially relatively low, increases, and then, in the Maine case, stabilizes for a period of 2 to 3 years, followed by a dramatic increase in a persisting attack. The information from Quebec indicates that high mortality levels continue following population declines. It is very important for a complete assessment of budworm mortality that those investigations involving continuous plot monitoring (e.g., Maine, Cape Breton, Newfoundland) be extended beyond the collapse of the outbreak.

The panel expressed several concerns about short-term mortality projections. One involved estimation of natural mortality based on historical data: the alternative is to derive the information from "protected areas" (studies in Cape Breton and Wisconsin). Another was that projections could not be reliably transferred to local situations, although they are useful for regional and large-area planning purposes. Finally, in regions like

Maine with relatively large protection programs, the effects of protection on mortality are confounded because spray operations shift annually depending upon the most recent hazard rating. That is, there is a high probability that most of the area is protected or partially protected at some time during the course of the outbreak. It is highly desirable to obtain an estimate of the unabated mortality pattern. The only sizable unprotected area in representative forests in Maine appears to be Baxter State Park. The Green Wood Project continuously monitors plots in the park and adjacent areas, but interim reports are not available. The soon-to-be-released New Brunswick survey will be highly relevant to an assessment of unabated mortality since the setback program there has been in place for a longer time and its magnitude in terms of total acreage is considerably larger than the recently announced setback program from Maine.

Loss from an inventory standpoint has two components—expected cumulative volume of dead trees that should have survived and expected versus realized volume of survivors. One panelist (Batzler) attempted a definition of growth loss: reduction in growth below the level which would have occurred in the absence of the agent disrupting the normal course of growth. Most of the other panelists bypassed a definition of loss in favor of citing recent examples of loss from their investigations. This is understandable. Gain and loss are difficult concepts, particularly loss. They are measured by differences in two endpoints separated in time. At least one of the endpoints must be capable of objective measurement, hopefully both, and then the difference must be evaluated by some means (gain, loss, status quo?).

The discussion on techniques for measuring growth loss was more animated. It was generally agreed that loss estimates based on radial increment at d.b.h. underestimated growth loss. Research by one of the panelists (Solomon) and others shows that taper increases rapidly and that bole diameter reduction beneath the crown is an immediate consequence of defoliation. Declining increment at breast height as a result of defoliation lags upper bole effects by 1 to 2 years. In small (ca 6 m [20 ft]), full-crowned, spaced fir there was no lag effect following defoliation (Piene—Nova Scotia).

One panelist cited recent estimates of growth loss in balsam fir ranging from 20 to 60 percent depending on defoliation levels, persistence, and stand conditions. Apparently there is little growth loss information on white and red spruce. Another panelist (Wright) commented that information techniques and those proposed did not consider reduced height growth, increased internal effects, top kill, nor procedures for estimating accretion that would have occurred on budworm-killed trees that otherwise would have survived.

Two techniques for improved growth loss estimates were described. Both relate the foliage contribution to growth to complete bole stem analyses. One involved a detailed analysis of foliage and foliage-related parameters (Piene-MacLean). The other estimates foliage weight by age class and employs a novel approach for this purpose (Solomon-Hyslett). Although the intended application of both is to improve estimates of growth loss, the second has another potentially useful application. If a generalized model were developed, it would be possible to estimate the quantity of 1 year foliage to be expected in an area. This estimate could be used to establish the upper limit for budworm populations in the area. In brief the technique, if validated, could be a useful tool for investigating population dynamics.

Finally, it should be noted that all discussion of growth and growth loss was framed in terms of gross rather than net volume. The silviculture discussions, particularly on windthrow, cited the high incidence of butt rot in living fir. At present we can only speculate on true budworm growth losses, especially in fir.

### **EMOFICO Meets**

Cathy MacLaggan, Chairperson for the Environmental Monitoring of Forest Insect Control Operations Committee (EMOFICO) reports a meeting was held at the Maritimes Forest Research Centre, Fredericton, N.B., on November 4, 1981. Twenty scientists representing 11 agencies discussed plans for the 1980-81 Report and expansion of the terms of reference of the Committee to include herbicides. A brief review of ongoing studies was also conducted. The group is scheduled to meet again when plans for the 1982 season have materialized. The 1980-81 Report should be ready for distribution before the 1982 operations season.

### **Forest Pest Control Forum**

Seventy-five delegates, representing forested land managers, associated resource managers, scientists, and research managers met in the Convention Centre in Ottawa, December 1-3, 1981, for the ninth annual Forest Pest Control Forum. As usual, the spruce budworm problem in eastern North America occupied a major portion of the agenda. Status reports were provided by all jurisdictions and the results of operations were discussed. Attention was focused upon several major issues including the registration protocols for biological materials, the use of pesticides for "surprises" like the spruce shoot moth, and the unexplained "crash" in Newfoundland. The Forum gives operators an opportunity to discuss their results and problems in an informal atmosphere and has been endorsed as a useful means to communicate early results. Jim Cayford, Director General of CFS Research and Technical Services, Tom Sterner, Director of the Forest Insect and Disease

Survey, and George Green, Director of the Forest Pest Management Institute shared the duties of Chairmanship.

The Environmental Committee of the Eastern Spruce Budworm Council took the opportunity to hold their annual meeting on the third day, which was scheduled for special interest groups.

### **Program Management Meeting**

While the Columbia Gorge winds howled outside, the annual Program Management meeting convened December 8-10, 1981, at the Menucha Lodge outside Portland. The sylvan setting, about 32 km (20 miles) from town, provided a tranquil atmosphere as managers from all CANUSA components met in the lodge's Great Hall in front of a 15-m (50-foot) Douglas-fir Christmas tree. Ron Stark and Chuck Buckner monitored the 3 days of discussion.

Fred Honing and Jack Armstrong led off with Data Sharing and Joint Registration of Pesticides. Fred attributed the slow progress in getting new compounds registered to the lack of industrial pursuit of registration on both sides of the border. Bob Lyon, from the USDA Forest Service's Washington Office, reviewed the list of candidate compounds proposed for registration and gave a status report on each. Of the materials under investigation, B.t. has been advanced; aminocarb, permethrin, and carbaryl have increased label uses; and several promising viruses, insect growth regulators, and fungi are being actively studied. Pheromone disruption trials were not successful, and more basic research is needed.

Jack Armstrong and Ron Stark chaired the discussion on Program Critique as a Joint Effort. They reviewed various elements of the Program that had been coordinated jointly—B.t., modelling, pheromones, and pesticide development—and concluded that all were more successful than if they had been pursued by a single agency. Several attendees suggested that greater advances might have occurred if there had been imposed standardization in data gathering.

The major conclusion was that although significant advances were made in several areas, resource managers have not been kept fully up to date about them. It was resolved to increase the emphasis on visible outputs of the Program. Discussion leaders Stark and Armstrong will consult with the Program Leaders and prepare a technology transfer strategy, incorporating the highly visible outputs of CANUSA, in an attempt to rapidly inform users of our major findings.

Dan Schmitt and Graham Page cochaired the discussion of the joint research symposium, by far the most spirited topic of the meeting. Participants agreed that the symposium will be held in a 4-day time frame during August-December 1984, somewhere in the eastern United States or Canada. Synopsis papers will be



Figure 7: Tom Sterner, Janet Searcy, and Bob Talerico (from the left) turn eyes right to concentrate on a remark from the other end of the table.

given on the state of the art in spruce budworm technology, including potential application of CANUSA findings. There will be poster sessions, agency and industrial exhibits, a banquet, and possibly a field trip.

The international symposium will be oriented to scientists but open to all. Stark and Page will investigate the possibility of tying the symposium to an IUFRO study group meeting planned for fall of 1984 or the joint Canadian Institute of Forestry/Society of American Foresters meeting in Quebec City August 5-9, 1984.

CANUSA will publish proceedings from this meeting, which will include the synthesis papers, wrap-up statements, and abstracts of the poster sessions. This document will probably be produced in Canada with joint U.S. responsibility. Speakers will be expected to secure peer review of their manuscripts 2 months before the meeting and hand in their papers at the meeting, to ensure timely publication in the first half of 1985.

Organization of the symposium will be handled by Program Leaders and their support staffs. A chairperson, probably someone from CANUSA management, will be selected; Graham Page, Bob Talerico, Ron Stark, and Doug Miller will be members of the organizing committee. The Program plans to let a contract, probably with retired USDA Forest Service employees, to handle the details. Support for this contract would come from Fiscal Year 1983 U.S. accelerated funds.

When Stark and Page have investigated the appropriateness of holding the symposium jointly with other meetings, they will report to Buckner and McKnight, who in turn will nominate the organizing committee. Future *Newsletter* items will keep our readers abreast of the plans that take shape between now and next December's Program Management Meeting.

The final topic at the 1981 meeting was a review of projected Program outputs, led by John Hudak and Janet Searcy. Three levels of cooperation manifested themselves during the discussion: (1) joint integrated research projects probably leading to multiauthored scientific publications, (2) joint projects where responsibilities are divided and where some outputs might be published jointly and some not, and (3) independent studies whose results fit the major plan but whose output would not warrant joint publication. Naturally this emphasis on joint productions does not take away from our concern about getting new technology into usable packages and transferring it promptly to users.

Janet gave participants a partial inventory of Program outputs from the American side, and she will prepare a reorganized list of publications by target areas, for examination on both sides of the border. Using this list, Program Management will suggest possible opportunities for joint authorship.

Ron and Doug will present to Program Management a joint technology transfer plan for the western components by February 1982. John and Dan will do the same for the eastern components.

Though not originally on the agenda, Transition Plan Phase II made a surprise appearance at the meeting, when Ron read it to the group. This was the first chance many of the Canadians had to hear about the various options being considered for extending CANUSA beyond September 30, 1983. Several participants expressed concern that the options do not provide for additional funds to supplement base funding for research (as opposed to applications-oriented studies) beyond 1983. It was agreed that the U.S. Program Managers will make recommendations on the options to Dr. Buckman, while Chuck will bring Canadian Forestry Service management up to date on this planning exercise.

Although we cannot yet say where the Program will be after September 30, 1983, we do know that the next Program Management meeting will be held December 7-9, 1982, somewhere in the Maritimes. The 1982 meeting will cover the symposium, transition planning, and how to translate Program outputs into practice with little or no time lag. Graham Page has been charged with finding a setting as lovely as Menucha Lodge and a Christmas tree at least as tall.

### **Spruce Budworm Models**

About 20 scientists attended a meeting of the Spruce Budworm Modelling Group held in Sault Ste. Marie, Ontario, January 19-21, 1982. A good balance of experience as well as some "new blood" was represented from such diverse areas of expertise as population dynamics, pathology, tree mensuration, and management. Bob Fisher, MFRC, did an admirable job of keeping the group on track. In attendance were some new members of CFS, which the CANUSA team would like to take this opportunity to introduce: Wilf Cuff, MFRC; Erhard Dobesberger, NeFRC; and Gary Whitfield, FPML.

Several group members gave presentations on their respective interests in modelling and these talks did much to encourage lively discussion. Among these presentations was one by Chris Shoemaker, Cornell, on comprehensive process models such as the Holling-Stedinger. The components of the model were looked at in a step-by-step fashion in an attempt to determine research needs. The recent "collapse" in Newfoundland was addressed and it was the general consensus of the group that such variations were not uncommon in budworm dynamics and that it would be futile to pursue the "collapse".



Figure 8. Just before leaving Menucha Lodge, Graham Page discovered the piano and accompanied (left to right) Martha Brookes, Mrs. Ben Moody, and Lloyd Sippell in singing Christmas carols.

Tom Royama, MFRC gave a talk on his analysis of the Green River data from 1945 to 1958. Never before and perhaps never again has such an intensive sampling procedure been conducted. These data are the best insight we have into budworm dynamics. There are, however, still a number of opinions on what caused the population cycles.

Wilf Cuff presented his approach based on the work he has done in Australia. His talk covered not only the mechanisms of an integrated ecosystem approach but also the philosophy and problems of model-directed research.

The general conclusion of the meeting was that a holistic approach such as CANUSA-West is using is not as applicable to the eastern situation. There are no definable needs for such a model at this time; however, there are some specific needs for the individual models. The most "useful" model, in the east, is the tree model in that it tries to address the needs of the user groups. We still lack the knowledge of how to link the budworm model to the tree model.

The group agreed that future meetings should be restricted to small groups with specific data needs.

### 1982 Defoliation Predictions—United States

Tom Hofacker, from Forest Pest Management (USDA Forest Service), has given us predictions for budworm defoliation expected in 1982.

| Region            | Defoliation Expected |           |
|-------------------|----------------------|-----------|
|                   | Acres                | Hectares  |
| Northern          | 1,000,000 +          | 404 695   |
| Rocky Mountain    | 1,300,000            | 526 103   |
| Southwestern      | 330,000              | 133 549   |
| Intermountain     | 1,800,000            | 728 450   |
| Pacific Northwest | 450,000              | 182 113   |
| Maine             | 4,000,000            | 1 618 778 |

### Item from the Press

**N.S. forest protection policy** — The lack of a provincial government forest protection policy, including the right to control insect infestation, is threatening the steady supply of wood fibre to Bowater Mersey Paper Company Ltd., assistant woodlands manager Jack Dunlop says.

He told senior media management and editorial staffers recently the company needs the policy in order to produce a 25 per cent increase in wood fibre yield from 700,000 acres of company woodlands over the next 10 years.

"If we want to continue to live, we must grow more wood fibre," Mr. Dunlop said. "And the only way to increase our growth is to bring our company owned acreage to a state where we can harvest 25 per cent more fibre annually."

Over the next 10 years, he said wood supply in the province will be in a "critical" stage as the after effects of the spruce budworm ravaged Cape Breton forests place increasing pressures on the mainland resource.

"Our biggest concerns are with growing and protecting our trees," he said, "and it is essential that forests companies and government be able to protect these forests from fire, insects, disease and hardwood forest competition."

(Chronicle Herald—November 6, 1981)  
Halifax, N.S.

### Recent Publications

From Pacific Southwest Forest and Range Experiment Station, 1960 Addison Street, Box 245, Berkeley, CA 94701, you may request a copy of:

Savin, N.E., and Jacqueline L. Robertson. "POLO 2: A user's guide to multiple Probit Or LOGit analysis." General Technical Report PSW-55, September 1981.

From Patti Kenney, USDA Forest Service, NPAS, 2810 Chiles Rd., Davis, CA 95616, the following computer-related user's manual is available: Dumbauld, R.K., J.R. Bjorklund, and S.F. Saterlie.

"Computer models for predicting aircraft spray dispersion and deposition above and within forest canopies: user's manual for the FSCBG computer program." Report 80-11. 270 pages.

These two journal articles are also worth noting:

Barry J., J. Wong, Patricia Kenney, L. Barber, H. Flake, and R. Ekblad. "Deposition of pesticide drops on pine foliage from aerial application." *Z. angew. Entomol.* 92 (1981) 224-232.

Barry, John W., and William M. Ciesla. "Managing drift in forest spray operations." *Aerial Applicator*, Nov./Dec. 1981, p. 8-9, 12, 17.

The Canadian Forestry Service submission to the Newfoundland and Labrador Royal Commission on Forest Protection and Management has been published as Information Report N-X-205. The title is "Review of the Spruce Budworm Outbreak in Newfoundland—Its Control and Management Implications," J. Hudak and A.G. Raske, eds., December 1981. This publication is a concise compendium of (1) the state of the art on all major aspects of the budworm, (2) current thinking on controversial issues of aerial spraying, and (3) a consensus of future development in budworm research. Although the climate, soils, forests, and human activities within the Newfoundland environment may not be applicable in all spruce budworm problem areas, the report serves as an example of an attempt to discuss a major forest pest in a comprehensive way. As such it should be of interest to wide range of entomologists, foresters, and ecologists. You may obtain a copy by writing the Director, Newfoundland Forest Research Centre, Building 304, P.O. Box 6028, Pleasantville, St. John's, Newfoundland A1C 5X8.

Dr. Ozzie Morris has released the Report of the 1980 cooperative B.t. spray trials. Ask for Report FPM-X-48, Forest Pest Management Institute, P.O. Box 490, Sault Ste. Marie, Ont. P6A 5M7

Finally, Information Reports Digest is a bi-monthly publication from the Canadian Forestry Service (CFS) that presents abstracts of all information reports published by CFS. If you wish to be put on the mailing list, write to CFS, Scientific and Technical Publications Unit, 19th Floor, Place Vincent Massey, Ottawa, Ont. K1A 0G5.